STRUVITE PRODUCTION AS A VALUE ADDED PRODUCT FROM HUMAN URINE

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C E R T I F I C A T E

This is to certify that the thesis entitled *"**Struvite Production as a value added product from Human Urine**"* submitted by **Mr. Chandana Bala Krishna** [Roll No. 111BT0493] in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Biotechnology at National Institute of Technology, Rourkela is an authentic work carried out by him under my guidance.

To the best of my knowledge the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any degree or diploma.

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A C K N O W L E D G E M E N T

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ABSTRACT

Human urine is rich in nutrients like Nitrogen, Phosphorus, Potassium, etc. Therefore, it can be used as a fertiliser in agriculture. Separate urine-collecting systems help in achieving maximum recovery of nutrients from urine without any harmful materials such as heavy metals. However, direct use of human urine as agricultural fertiliser is associated with many problems such as handling, storage, transport, nutrient loss to the atmosphere and spreading on arable land. Therefore, to overcome these difficulties human urine is processed for capturing the nutrients present in it into solid mineral form. On addition of small amounts of $MgSO_4$ to human urine major amounts of phosphorus, potassium and nitrogen were precipitated, with struvite ($MgNH_4PO_4.6H_2O$) as a major component. Struvite precipitation is influenced by many factors like $MgSO_4$ dosage, temperature, pH. Therefore, optimisation of these parameters is need to be done for effective struvite recovery. Different experiments were conducted to know the optimum value of each parameter by keeping other to parameters constant. The optimum pH for struvite precipitation was found to be around 10.2. Struvite precipitation was high at normal room temperatures. Different $MgSO_4$ dosages were tested to know the optimised dosage, where there was maximum struvite formation by keeping pH and temperature constant.

KEY WORDS: Human urine, Struvite, Agricultural fertiliser, nutrient recovery.

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CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

Human waste removal is an important part of daily life and is an important factor in human health. The goal of the present day sanitation systems is to prevent exposure of humans to the harmful pathogens that are found in this waste. Apart from these harmful pathogens, human waste also consists of many valuable nutrients that are being lost in human waste water systems. Waste water management systems should be designed for the recovery of these nutrients. Most of the nutrients that come out of waste water systems are from human urine. Around 94% of the nitrogen (N), phosphorus (P) and potassium (K) in waste water systems radiates from the urine, along with other micronutrients (Bo-Bertil Lind, 1999). Percentage loss of N, P, K as wastes from different sources are given in table.1.

Table 1: Percentage loss N, P, K as wastes from different sources (Ganrot, 2005).

Type of Waste	Nitrogen	Phosphorus	Potassium
From industries	8	10	15
From Trade	5	4	6
Domestic(kitchen)	15	26	18
Urine	64	43	52
Faeces	7	22	9

Separate urine collecting toilets are a possible solution for efficient recovery of nutrients from the urine. Urine separation has many advantages as it relieves the conventional waste water systems from harmful micro pollutants present in urine and enables high nutrient recovery. Energy efficiency analysis of waste water treatment plants demonstrates that phosphorus and nitrogen recycling efficiency is high if the urine is collected separately (Hellstorm, 2002).

At the same time, soils are losing nutrients due to extensive use of artificial chemical fertilisers (karak, 2010). Many kinds of chemical fertilisers are used, but the materials to create them are getting increasingly hard to obtain. Majority of these chemical fertilisers are made using phosphorus, nitrogen and potassium which come from finite resource pools. Most of the nitrogen is from natural gas and is subject to availability of methane and price changes (shaw, 2010). For phosphorus, there is no substitute in nature. It is evaluated that there are 7000 million tonnes of phosphate rocks as P_2O_5 is available in reserves that could be economically mined (Survey, 2005). It is estimated that every year phosphorus demand will increase by 1.5%. Accordingly, in 100-250 years the resource could be exhausted (Steen, 1998). The main nutrients that are being excreted through urine are given in table.2. These factors increased the use of human urine as a fertiliser.

Table 2: some of the nutrients present in urine and their nutrient values (Dittmer, 1974).

Nutrient	Amount excreted (mg/kg body weight. day)	Amount excreted (g/person.day)
Calcium	5.75	0.40
Sulphur	16.00	1.12
Magnesium	1.35	0.10
Potassium	34.00	2.38
Phosphorus	12.00	0.84
Nitrogen	215.00	15.05

However, direct use of human urine as agricultural fertiliser is associated with many problems such as handling, storage, transport, nutrient loss to the atmosphere and spreading on arable land. A large portion of issues associated with urine separation could be met by changing the nutrients in the urine into solid minerals. Handling and storage could be considerably enhanced, the volume would be significantly diminished compared with the liquid urine, loss of nitrogen into the environment would be reduced, cleanliness could be maintained, and spreading on arable area could be substantially more as far as time and dosage are considered.

Conversion of nutrients present in the urine into solid minerals could be achieved by many methods. Currently, magnesium ammonium phosphate (MAP) precipitation technology of recycling N and P is receiving focus by the scientists and industrialists (Etter, 2011). The MAP hexahydrate ($MgNH_4PO_4.6H_2O$) is called Struvite. Struvite is considered as a slow release fertiliser that is soluble in acid not in water, alkali, and ethanol (Le Corre, 2009).

On addition of small amounts of $MgSO_4$ to human urine major amounts of phosphorus, potassium and nitrogen were precipitated, with Struvite as a major component. Struvite precipitation depends on the amount of $MgSO_4$ added to the urine, pH of the urine, temperature of the urine. Different experiments were conducted to know the optimum value of each parameter by keeping other to parameters constant.

CHAPTER 2

LITERATURE REVIEW

2.0 LITERATURE REVIEW

In this chapter, the methods that were used for struvite precipitation in different articles, journals were discussed.

2.1 What is urine?

Human urine is a fluid waste product of the human body emitted by the kidneys by a procedure of filtration from blood called Urination and discharged through the urethra. As urine is produced after filtration of the blood in kidneys, it contains low molecular weight compounds as proteins are not filtered.

2.2 Generation rate of urine per person

On an average 1-1.5 L of urine is produced by each individual every day. An adult person excretes on average of 500L urine per year (Tanmoy Karak, 2010). However, children urinate about half of that of the adult’s amount.

2.3 Composition of human urine

Urine contains majority of day by day discharge of nitrogen (N), phosphorus (P) and potassium (K) contributing 88%, 67% and 73% separately of all the human excreta. However, human urine composition changes from individual to individual, from area to area depending on food habits, consumption of drinking water, body size, and environmental factors. In human urine around 75-90% of N discharged is urea and the rest is discharged in the form of uric acid, creatinine and amino acids. The vast majority of the nitrogen in urine is taken up by the plant and which is same as that of the ammonium fertiliser or urea with nitrogen efficiency nearly 90% of that of mineral fertiliser. Human urine also contains low concentration of heavy metals. Heavy metals concentration in urine is lower than that of manure in farmyard. Apart from this, human urine has less cadmium than artificial fertilisers, making it clean fertiliser. Also, human urine consists of trace elements Cu, B, Zn, Fe, Co, Mn and Mo.

Human urine is not completely sterile as it contains small amount of different microorganisms. These microorganisms can be disinfected easily by adding urine directly to the soil or by storage. On the other hand, urine is considered as sterile, unless cross contamination occurs from other human excreta leading to possible persistence of viruses, and can be used as plant fertiliser without any other treatment processes.

Table 3: Urine constituents in decreasing concentration (NASA, 2000).

Sl.no	Constituents in urine	Concentration(gram/litre)
1	Urea	9.3
2	Chloride	1.87
3	Sodium	1.17
4	Potassium	0.750
5	creatinine	0.670

Apart from the above mentioned constituents urine also contains other dissolved ions, organic and inorganic compounds such as electrolytes, enzymes, fatty acids, vitamins, etc.

2.4 Characteristics of human urine

2.4.1 Colour

Typically, the colour of urine ranges from colourless to yellow-amber. Colour varies according to recent diet and the urine concentration. Drinking more water reduces the concentration of the concentration and therefore makes it to have a lighter colour.

Colour of urine is due to the presence of Urobilin. Urobilin is a final waste product from the breakdown of 'heme' from 'haemoglobin'. Colour changes in urine provide health information as shown in Table 3.

2.4.2 Smell

Normally, fresh urine has mild smell but aged urine has a stronger smell same as that of ammonia.

Table 4: Colour changes in urine providing health information (NASA, 2000).

Sl.no	Urine colour	Indication
1	Dark yellow	Dehydration
2	Yellowing/light orange	Excess b-vitamin removal from blood stream.
3	Orange	Due to certain medications such as Vifampin and Phenazopyridine.
4	Dark orange to Brown	Jaundice symptom.
5	Blue urine	Ingestion of Methylene blue in medications.
6	Greenish urine	Consumption of Asparagus.
7	Black or dark coloured urine	Melanuria, caused by melanoma.
8	Pinkish urine	Beets consumption
9	Purple urine	Due to Purple urine bag syndrome.
10	Reddish or brown urine	Porphyria.

2.4.3 Turbidity

Turbidity of urine samples are reported as clear, slightly cloudy, cloudy, opaque or flocculent. Generally, fresh urine is clear or very slightly cloudy.

Main reasons for changes in turbidity are increased cells (Red Blood Cells, White Blood Cells), bacteria, numerous crystals, semen or faecal contamination.

2.4.4 Density or Specific gravity

The density or specific gravity values of normal urine ranges between 1.003 – 1.035 gram/cubic centimetre (Martín Hernández E, 2001). The changes in density are associated with urinary disorder.

2.4.5 pH

pH values of human urine ranges from 5.6 to 8, with a typical average being around 6.0 (Bo-Bertil Lind, 1999). Variations in pH of human urine are due to changes in diet.

2.5 Large scale urine isolation

Isolating human urine at source improves the supportability and efficiency of waste water treatment plants as human urine containing about 80% of the total nitrogen present in wastewater. Effluent quality could be significantly enhanced and energy utilization, investment costs of the waste water treatment plants could be saved by source separation of human urine. On the other hand, human urine separated in this way could be directly used as a liquid fertiliser. When faeces gets mixed with urine, the mixture gets hard to handle hygienically, outside the waste water treatment plants. Ecological sanitation (ECOSAN) toilets or no-mix toilets or urine diversion (UD) toilets have been designed to overcome this issue (Larsen TA, 1996). Human urine is separated at source by these toilets for better nutrient recycling purpose. A schematic diagram of these toilets is shown in Fig.1. Many developed and developing countries such as China, Germany, France, Mexico, USA, Finland, Ethiopia, Ecuador, South Africa, Sweden, Nepal, Thailand, Vietnam and Zimbabwe have been successfully adopted to these urine diversion (UD) sanitation technology.

ECOSAN approach gives a basic understating of wastewater treatment systems in which urine (yellow water), faeces (brown water) and gray water are not considered as pollutants but instead as useful and valuable resources. Yellow, grey, brown, etc. are the “new colours of ecological sanitation” (Otterpohl, 2003). Various examples of ECOSAN systems with source separation, treatments and utilisation are given in Fig.2.

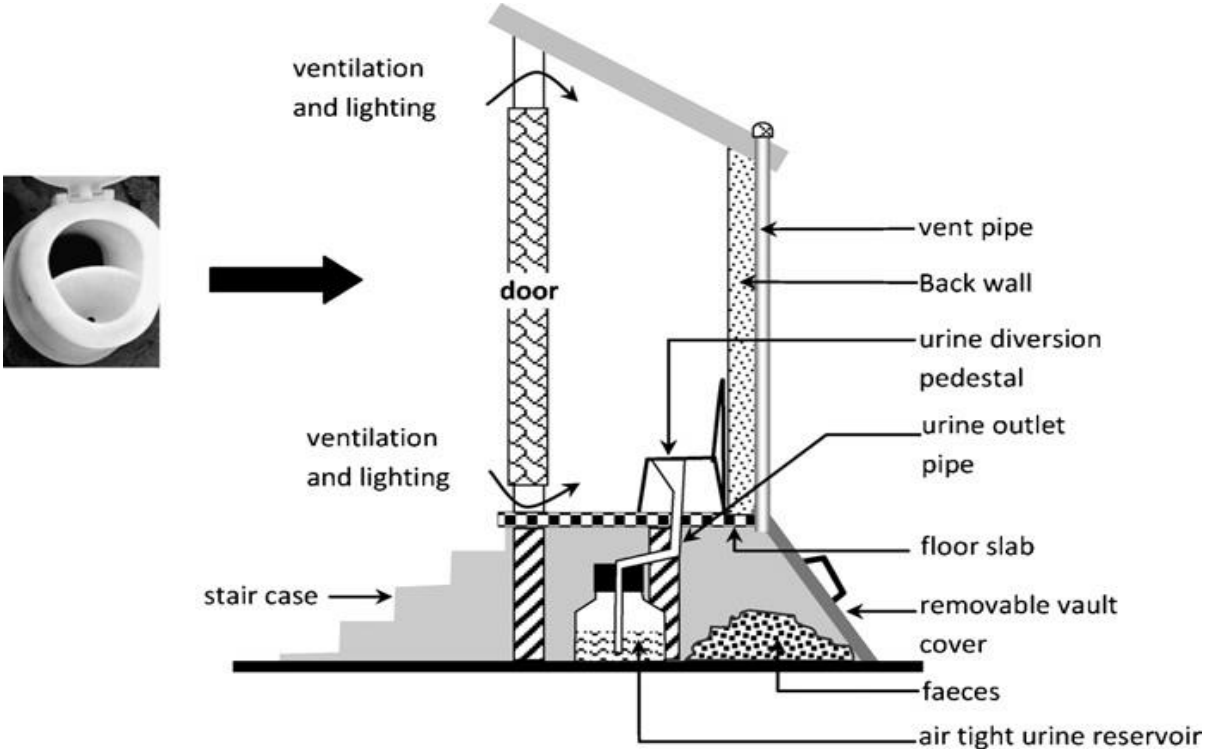

Figure 1: Schematic diagram of UD toilets (taken from: (Larsen TA, 1996)).

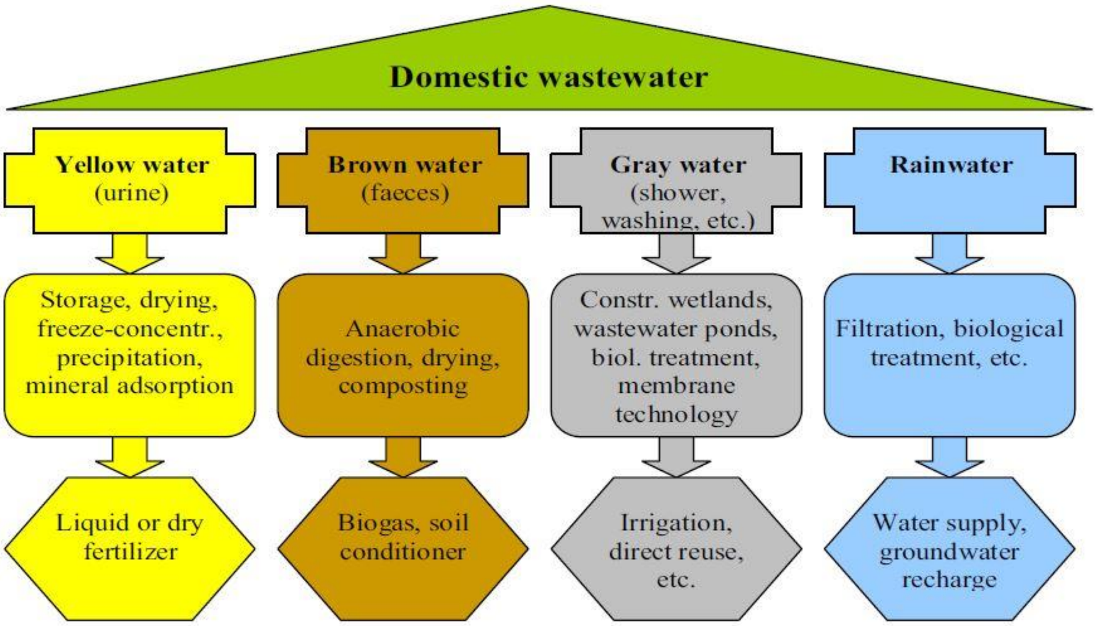

Figure 2: Various examples of ECOSAN systems with source separation, treatments and utilisation (Ganrot, 2005).

2.6 Human urine storage

Storage of human urine is important before its use as an agricultural fertiliser. During storage, the loss of nitrogen to the environment can be reduced by not allowing aeration above the liquid surface in storage tanks, and by minimizing the temperature. For unrestricted use of human urine with respect to viable viruses and pathogens, it is recommended that the storage period should be 6 months at 25^{o}C or higher (Vinnerås B, 2008).

2.7 Urea hydrolysis

Major problem of urine separation systems is blockages caused by inorganic precipitates. Bacterial urease present in the urine collecting pipes hydrolyses the urea present in human urine. This hydrolysis of urea is the trigger of precipitation, responsible for blockages. Urease active bacteria mainly grow in the pipes and are flushed into the collection tanks. Both bacteria and free urease are responsible for urea hydrolysis. Within few days, complete urea present in the collection systems can be depleted. The precipitating minerals that are responsible for blockages are struvite and octacalcium phosphate (OCP). Struvite precipitates at low saturation levels, while OCP precipitation starts at a high level of saturation. The final calcium phosphate mineral that is present in urine solutions is hydroxyapatite (HAP). OCP slowly transforms into HAP as it is only a precursor phase (Kai M. Udert, 2003). The blockage of pipes due to struvite precipitation is shown in Fig.3.

Figure 3: Blockage in pipe due to struvite precipitation (taken from: (www.crystalenv.com/struvite_pipe, n.d.)).

The collecting tank and pipes having high activity of urease will have rapid precipitation of magnesium and calcium phosphates. Primarily, urease active bacteria is grown in collection tanks and pipes. Therefore, long pipes enhances urea hydrolysis. Free urease is found in collection tank by the lysis of urease active bacteria. Around 20% of urease activity is because of this free urease. (Kai M. Udert, 2003)

2.8 Struvite ($MgNH_4PO_4.6H_2O$)

2.8.1 Sources of struvite components

Ammonium:

In waste water, ammonium sources are hard to quantify because they are created in-situ during the nitrogenous material degradation. Sources of ammonia are present in waste water due to the presence of urea. Relative to phosphorus and magnesium, ammonium is present in excess in waste water (Schultze-Rettmer, 1991).

Phosphorus:

In human urine, the concentration of phosphorus can be used as an indicator of potential for recovery. Phosphorus in household sewage generally enters a waste water treatment plant as bioavailable, dissolvable, orthophosphates; H_2PO_4, HPO_4^{2-}, PO_4^{3-}. Obviously, there will be variations in concentrations, but reasonable level of phosphorus to expect is 10 mg/l (Strickland, 1999).

Magnesium:

Magnesium levels in the waste water stream to treatment can originate from various sources. If the waste water treatment plant is situated in a hard water area, then the magnesium particles that are present will be in abundance. Additionally, if the water treatment plant is in a seaside (coastal) region, then the sea water entering the plant can be a source of magnesium (Fujimoto N, 1991).

In some waste water treatment plants, adding support material to anaerobic digesters is a common practice. The support material gives a surface area to biomass to get attached and thus helps in preventing biomass from being removed with the effluent. The material utilised as supports, can be a magnesium source.

In laboratory scale, magnesium salts are added to stored urine for struvite crystallisation. These salts act as the magnesium sources under these circumstances. Commonly used magnesium salts for struvite crystallization are MgO, $MgCl_2$, and $MgSO_4$.

2.9 Struvite precipitation

Human urine is a complex aqueous solution containing Urea ($CO(NH_2)_2$), and sodium chloride (NaCl) as predominant compounds. Additionally, calcium (Ca), potassium (K), phosphate (PO_4) and sulphate (SO_4) are present in low concentrations (Bo-Bertil Lind, 1999). Struvite ($MgNH_4PO_4.6H_2O$), formed by the reaction of magnesium with ammonical phosphate solutions is the most important compound that can precipitate from human urine. Relative to phosphorus, human urine contains an excess of ammonia, but it is deficient in magnesium. Therefore magnesium sources are added to human urine for struvite precipitation. The ordinary pH of human urine ranges from 5.6 to 6.8. Under normal conditions, large portion of phosphate is present as HPO_4^{2-} or H_2PO4^-. After adding $MgSO_4$, the pH of urine increases and this shifts the equilibrium of phosphate towards PO_4^{3-}, providing magnesium for struvite crystallization. The overall reaction for struvite precipitation is given below.

$$Mg^{2+} + NH_4^+ + PO_4^{3-} + 6H_2O \longrightarrow MgNH_4PO_46(H_2O)$$

CHAPTER 3

MATERIALS AND METHODS

3.0 MATERIALS AND METHODS

In this chapter, various methods required for struvite production were discussed. Apart from this, methods required to know the effect of $MgSO_4$ dosage, pH, and temperature on struvite precipitation were discussed.

3.1 Urine collection and storage

Human urine was collected from 3 individuals for 3 days. The collected urine was stored for 25 days at room temperature in a closed container. The container was closed tightly without any aeration over the liquid surface.

3.2 Ureolysis

Most of the nitrogen in human urine is present in the form of urea. During the storage time urea hydrolysis takes place resulting in pH increase due to ammonia release. Ureolysis is triggered by urease enzyme (urea amidohydrolase). This enzyme hydrolyses urea to ammonia and carbamate. This carbamate decomposes to carbonic acid and a second molecule of ammonia.

The overall ureolysis reaction can be written as:

$$NH_2(CO)NH_2 + 2H_2O \longrightarrow NH_3 + NH_4^+ + HCO_3^-$$

Generally, the urease enzyme is produced by different types of prokaryotic and eukaryotic organisms, out of which bacteria is most abundant. This bacteria is widely present in aquatic environments, soils and in human intestines. The bacteria present in human intestinal are responsible for formation of stones in kidneys. In this case, this bacteria is responsible for the hydrolysis of urea.

Measured the pH of the stored urine using Digital pH Meter.

3.3 Struvite precipitation

This experiment was done to know whether the struvite is formed or not. The protocol for this experiment was given below:

- 100 ml glass beaker was taken and washed properly.
- 90 ml of stored urine was taken in the glass beaker.
- 0.5g of magnesium sulphate heptahydrate ($MgSO_4$) was added to the urine.

- Then the beaker was closed using aluminium foil making sure that there was no aeration over the liquid surface.
- Then the glass beaker was kept on magnetic stirrer at high rpm (400) for 2 minutes to enable fast mixing.
- After that the rpm was reduced (to 160 rpm) and maintained the same rpm for 20 minutes
- After 20 minutes the glass beaker was kept undisturbed for overnight, for the precipitation to take place.
- Next day the precipitated material was collected using filter paper.
- Then it was dried at room temperature.
- The dry precipitate was weighed using weighing balance and the weight was noted.

3.4 Effect of $MgSO_4$ concentration on struvite precipitation

A set of experiments was done to know the effect of $MgSO_4$ dosage on struvite formation and to find the optimum amount of salt to be added for effective struvite formation. Different dosages of $MgSO_4$ (0.0g, 0.03g, 0.05g, 0.1g, 0.25g, 0.5g, 0.75g, 1.0g) were added to 30 ml of urine samples. pH and temperature were kept constant throughout these experiments. Then the weights of the precipitate formed for different dosages were noted down and based on these values, the optimum dosage of $MgSO_4$ to be added to urine for efficient struvite precipitation was determined. The protocol for each experiment was same and given below:

- 100 ml glass beaker was taken and washed properly.
- 30 ml of stored urine was taken in the glass beaker.
- Different dosages of magnesium sulphate heptahydrate ($MgSO_4$) was added to the urine.
- Then the beaker was closed using aluminium foil making sure that there was no aeration over the liquid surface.
- Then the glass beaker was kept on magnetic stirrer at high rpm (400) for 2 minutes to enable fast mixing.
- After that the rpm was reduced (to 160 rpm) and maintained the same rpm for 20 minutes
- After 20 minutes the glass beaker was kept undisturbed for overnight, for the precipitation to take place.
- Next day the precipitated material was collected using centrifuge.

- Then it was dried at room temperature.
- The dry precipitate was weighed using weighing balance and the weight was noted.

3.5 Effect of pH on struvite precipitation

A set of experiments was done to know the effect of pH on struvite formation and to find the optimum pH required for effective struvite formation. The experiments were conducted at different pH values (8.53, 8.60, 8.76, 8.93, 9.2, 9.46, 9.7, 9.99, 10.2, 10.33, 10.5) keeping the $MgSO_4$ dosage and temperature constant. Then the weight of the precipitate formed for different pH of urine was noted down and based on these values, the optimum pH required for efficient struvite precipitation was determined. The protocol for each experiment was same and given below:

- 100 ml glass beaker was taken and washed properly.
- 30 ml of stored urine was taken in the glass beaker.
- The pH of urine was changed by adding 1 normal (N) Sodium Hydroxide (NaOH).
- Then 0.1g of $MgSO_4$ was added to the urine.
- Then the beaker was closed using aluminium foil making sure that there was no aeration over the liquid surface.
- Then the glass beaker was kept on magnetic stirrer at high rpm (400) for 2 minutes to enable fast mixing.
- After that the rpm was reduced to (160 rpm) and maintained the same rpm for 20 minutes.
- After 20 minutes the glass beaker was kept undisturbed for overnight, for the precipitation to take place.
- Next day the precipitated material was collected using centrifuge.
- Then it was dried at room temperature.
- The dry precipitate was weighed using weighing balance and the weight was noted.

3.6 Effect of temperature on struvite precipitation

A set of experiments was done to know the effect of temperature on struvite formation and to find the optimum temperature required for effective struvite formation. . The experiments were conducted at different temperatures (10^oC, 20^oC, 25^oC, 30^oC, 35^oC, 40^oC) keeping the $MgSO_4$ dosage and pH constant. Then the weight of the precipitate formed for different temperatures of urine was noted down and based on these values, the optimum temperature required for efficient struvite precipitation was determined. The protocol for each experiment was same and given below:

- 100 ml glass beaker was taken and washed properly.
- 30 ml of stored urine was taken in the glass beaker.
- The temperature of the urine was changed using freezer and magnetic stirrer.
- Then 0.1g of $MgSO_4$ was added to the urine.
- Then the beaker was closed using aluminium foil making sure that there was no aeration over the liquid surface.
- Then the glass beaker was kept on magnetic stirrer at high rpm (400) for 2 minutes to enable fast mixing.
- After that the rpm was reduced (to 160 rpm) and maintained the same rpm for 20 minutes
- After 20 minutes the glass beaker was kept undisturbed for overnight, for the precipitation to take place.
- Next day the precipitated material was collected using centrifuge.
- Then it was dried at room temperature.
- The dry precipitate was weighed using weighing balance and the weight was noted.

CHAPTER 4

RESULTS AND DISCUSSION

4.0 RESULTS AND DISCUSSION

In this chapter, the results obtained were given and discussed. Initially, $MgSO_4$ was added to fresh urine, but there was no precipitation. This was already proved by (Kai M. Udert, 2003) Therefore, the urine was stored for the urea hydrolysis to occur.

4.1 Urea hydrolysis

Initial pH of the collected urine was found to be 5.8. After storing for 25 days the pH has increased to 8.53. This increase in pH is due to ammonia release by urea hydrolysis. During the storage, bacteria present in the urine produced urease enzyme which might triggered the ureolysis.

4.2 Struvite Precipitation

When 0.5g of $MgSO_4$ was added to 90 ml of urine, struvite was formed. The weight of the struvite precipitated was found to be 0.182g.

Figure 4: Urine before adding $MgSO_4$

Figure 5: Urine after adding $MgSO_4$

4.3 Effect of $MgSO_4$ concentration

The experiments were carried out at constant pH 8.53 and at room temperature. The weight of struvite formed increased till 0.1g of $MgSO_4$ and from there the struvite formation was almost constant. There was an increase in struvite precipitation till 0.1g because till then the ammonia and phosphates present in the urine are in excess when compared to magnesium added. For 0.1g $MgSO_4$, the total ammonia and phosphates present in the urine were precipitated. Therefore, for dosages above 0.1g, the struvite formation was found to be almost same. Fig.7 gives the information about percentage increase of struvite formation with increase in magnesium dosage.

Table 5: Amount of Struvite formed for different dosages of $MgSO_4$

Ex.No	Volume of urine sample (in ml)	Initial pH	$MgSO_4$ added (in gm)	Struvite formed (in gm)	Final pH
1	30	8.53	0.0	0.009	8.97
2	30	8.53	0.03	0.011	8.97
3	30	8.53	0.05	0.023	8.94
4	30	8.53	0.1	0.054	8.92
5	30	8.53	0.25	0.046	8.91
6	30	8.53	0.5	0.058	8.89
7	30	8.53	0.75	0.056	8.88
8	30	8.53	1.0	0.052	8.9

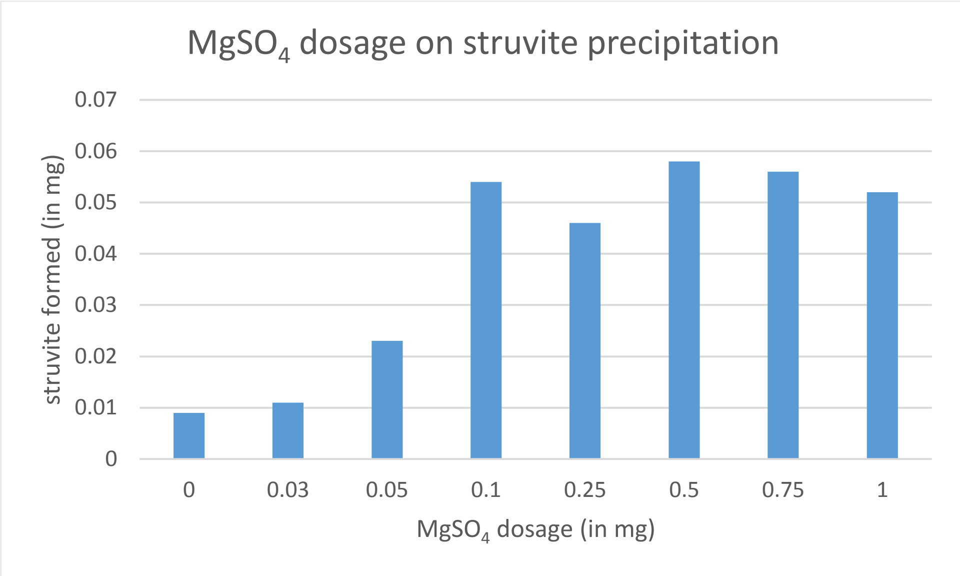

Figure 6: Effect of $MgSO_4$ dosage on struvite formation..

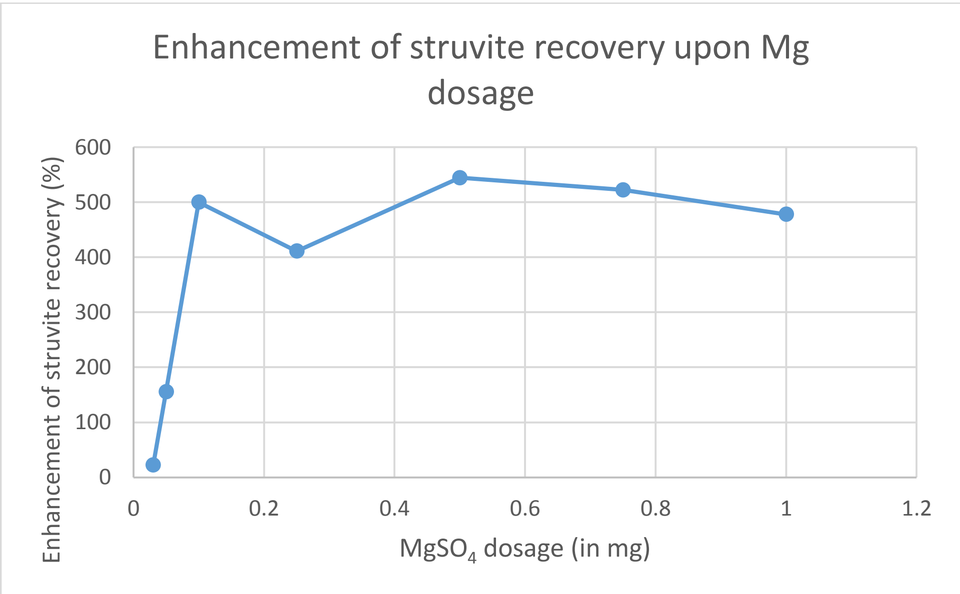

Figure 7: Effect of $MgSO_4$ dosage on enhancement of struvite recovery (%).

4.4 Effect of pH

The experiments were carried out by keeping the $MgSO_4$ dosage constant (0.1g) at room temperature. There was an increase in struvite formation with the increase in pH till the value of pH reaches to 10.2. For pH above 10.2, there was a decrease in struvite formation. Fig.9 gives the information about percentage increase of struvite formation with increase in pH of the urine.

Table 6: Amount of struvite formed for different pH values of urine

Ex.No	Volume of urine sample (in ml)	$MgSO_4$ added (in gm)	pH	Struvite formed (in gm)
1	30	0.1	8.53	0.052
2	30	0.1	8.6	0.054
3	30	0.1	8.76	0.048
4	30	0.1	8.93	0.063
5	30	0.1	9.2	0.075
6	30	0.1	9.46	0.094
7	30	0.1	9.7	0.123
8	30	0.1	9.98	0.147
9	30	0.1	10.2	0.182
10	30	0.1	10.33	0.17
11	30	0.1	10.5	0.12

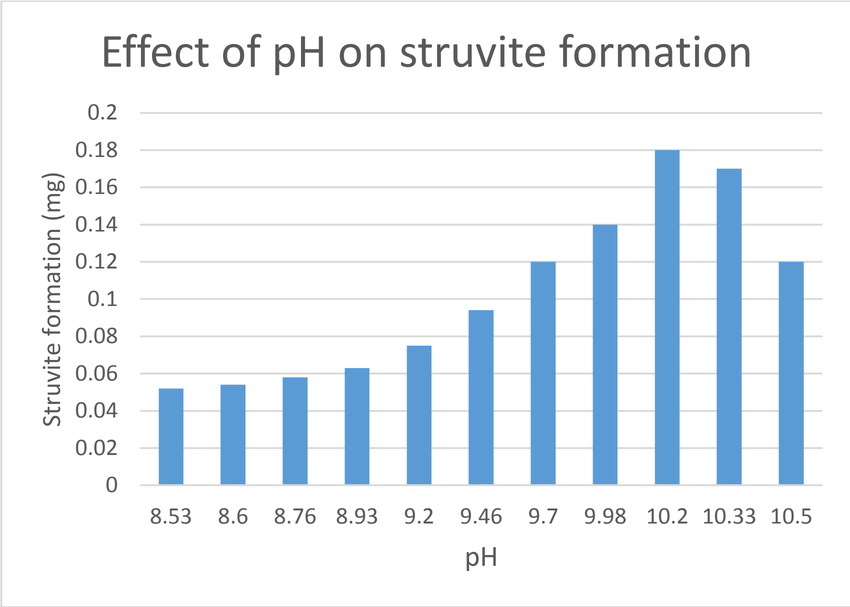

Figure 8: Effect of pH on struvite formation.

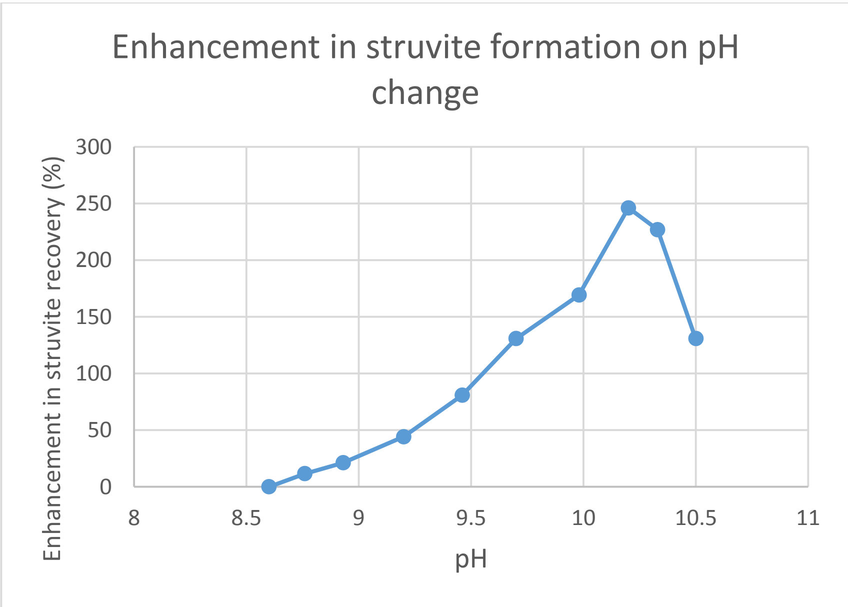

Figure 9: Effect of pH on enhancement of struvite formation (%).

4.5 Effect of temperature

The experiments were carried out keeping the $MgSO_4$ dosage (0.1g) and pH (8.53) constant at different temperatures. At lower temperatures, the struvite formation was very less. As the temperature increased the struvite formation was increased. Fig.11 gives the information about percentage increase of struvite formation with increase in temperature.

Table 7: Amount of struvite formed for different temperatures of urine.

Ex.No	Volume of urine sample (in ml)	$MgSO_4$ added (in gm)	pH	Temperature (in ^oC)	Struvite formed (in gm)
1	30	0.1	8.53	10	0.02
2	30	0.1	8.53	20	0.032
3	30	0.1	8.53	25	0.043
4	30	0.1	8.53	30	0.052
5	30	0.1	8.53	35	0.054
6	30	0.1	8.53	40	0.049

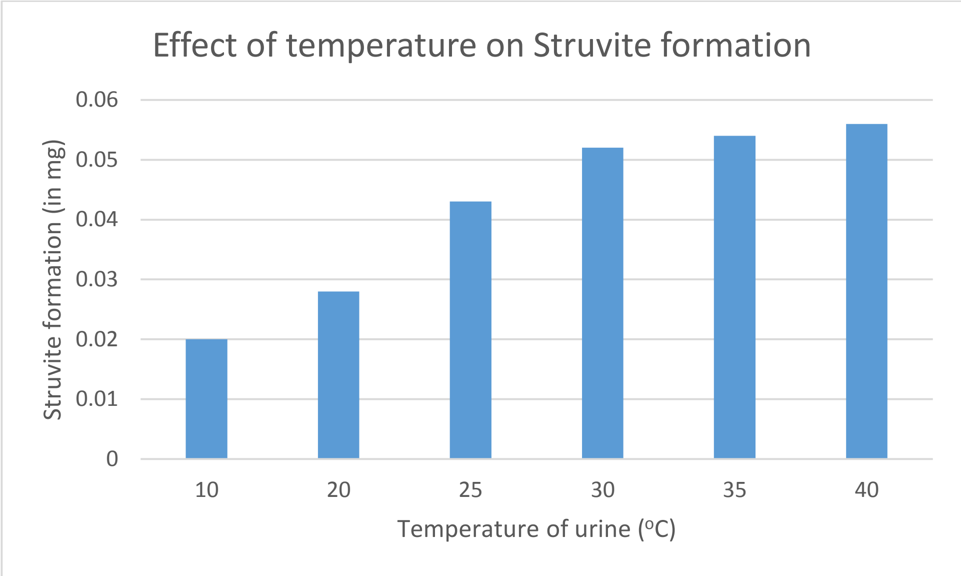

Figure 10: Effect of temperature on struvite formation.

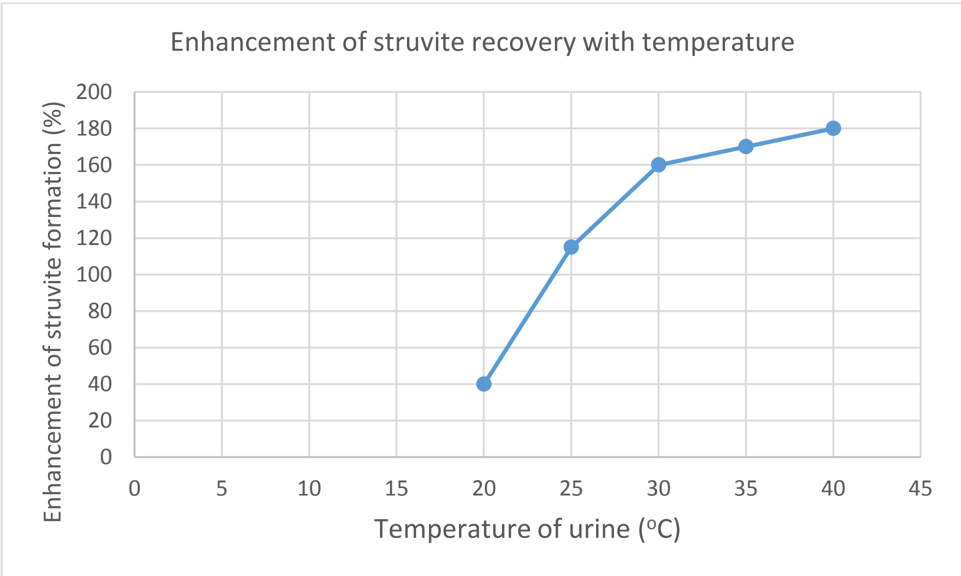

Figure 11: Effect of temperature on enhancement of struvite formation (%).

Figure 12: Struvite recovered from the above experiments.

Based on the above results, the average amount of struvite that can be obtained from an adult person per day, per week, per month, per year was calculated. At the same time, the amount of $MgSO_4$ required for the struvite formation was calculated.

Table 8: Estimation of struvite production from an adult person.

Average urine produced by an adult person	**$MgSO_4$ needed (in kg)**	**Struvite that can be obtained (in kg)**
1.5 l/day	0.005	0.01
8.7 l/week	0.029	0.058
41.6 l/month	0.139	0.278
500 l/year	1.67	3.334

CHAPTER 5

CONCLUSION

5.0 CONCLUSION

Struvite precipitation can be done by adding magnesium sulphate as magnesium source. Therefore, many problems associated with human urine such as handling, storage, transport, nutrient loss to the atmosphere and spreading on arable land, for its use as an agricultural fertiliser can be overcome by adding magnesium sulphate. The struvite precipitation can be optimised by varying parameters like temperature, pH and $MgSO_4$ dosage. The optimum pH of urine for struvite precipitation was found to be 10.2. The experiments have shown that the struvite precipitation is high at room temperature.

The experiments were carried out by using separately collected urine. This shows that the recovery of nutrients from separated urine could play a major role in urban sanitary systems.

CHAPTER 6

SCOPE FOR FUTURE WORK

6.0 SCOPE FOR FUTURE WORK

- Extensive characterisation of human urine has to be done to understand the influence of other ions present in the urine.
- Studies on role of urease have to be considered for effective urea hydrolysis and to shorten the storage time of urine.
- Extensive characterisation of formed struvite has to be done to understand the effectiveness of struvite as a fertiliser.
- Electron microscope, energy dispersive X-ray analysis (EDS) and X-ray diffraction (XRD) analyses of the struvite precipitates have to be done for their characterisation.

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